remainder of the house by using plastic sheeting. This has the effect of blocking any natural convective air currents from moving through the attic. This artificial environment has the effect of inflating the apparent airborne concentrations.

One additional significant problem with the Ewing study is the lack of observed chrysotile fibers in the air samples from the ceiling penetration test. In this test, a hole was sawed into the ceiling by the worker using a compass saw. As identified by MAS (sample M29780-007a), the ceiling plaster contained 7% chrysotile by volume. However, no chrysotile was reported in any air sample collected during the test and analyzed by TEM. MAS has claimed in the past[39] that simply abrading asbestos-containing plaster generates airborne asbestos concentrations, which they have characterized as very high. Failure to find even one chrysotile fiber makes the credibility of the analysis a significant concern.

1. Conversion to PCME/Impact of Counting Cleavage Fragments

Many of the TEM structures that are reported in the Claimant simulations are shorter than 5 μm. As discussed in the literature and at a recent expert panel hearing[40], fibers shorter than 5 μm pose no excess risk for the causation of either lung cancer or mesothelioma. As such, exposure study data should be restricted to those fibers that have been shown to be related to lung cancer and mesothelioma (PCME asbestos fibers) as incorporated into the EPA and OSHA risk models. The exposure studies summarized in Tables 4-5 have had the TEM data evaluated to determine the PCME fiber concentration, excluding the fibers < 5 microns in length. These

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39 W. Longo and R. Hatfield (1999). *Kelly-Moore: Mixing, Applying, Sanding & Cleanup of Asbestos Containing Finishing Compound – Work Practice Study*, Materials Analytical Services, Inc.

fibers are the only sizes that relate to the risk factors determined for EPA's IRIS and used in OSHA's risk model.

These PCME particles were then further evaluated to determine if they were asbestos fibers or cleavage fragments using the same algorithm as was used for the EPA Phase 2 data. More than half of the PCME-sized particles in the Longo studies were identified as cleavage fragments. Ninety-three percent of the PCME-sized particles in the Ewing study were identified as cleavage fragments. These percentages are consistent with other studies and inflate reported asbestos concentrations.

2. Impact of Containment/No Ventilation on Air Sample Results

The reports issued by Claimants' experts do not specify the airflow in the attics that were tested. Most attics have gable vents or a ridge vent that forms a natural convective current from the house through the attic and to the outdoors. This current of air, as measured by Lees and Mlynarek, acts to carry any airborne particulate out of the attic and away from the worker/homeowner. When the rooms are artificially separated from the rest of the house, such as in Ewing, et al., this air current is disrupted, causing airborne particulate to artificially concentrate in the attic air. This artificially inflates the resulting concentrations.

3. TWA Calculations

Continued from previous page

40 ATSDR (2002). "Expert Panel on the Health Effects of Asbestos and Synthetic Vitreous Fibers (SVF): The Influence of Fiber Length", Panel meeting, New York, NY, October 29 – 30, 2002, meeting handout.

Ewing incorrectly refers to his reported average airborne concentrations measured during the simulations as "TWA" concentrations. In fact they are task concentrations, reflecting only the airborne concentrations during the performance of the simulation. OSHA has established an 8-hour standard to which an employee may be exposed over his/her working lifetime without restriction. Comparisons of actual exposures with this standard are adjusted to their eight-hour time weighted average. It is generally accepted within the industrial hygiene and regulatory community that the acronym "TWA" refers to the OSHA eight time-weighted average. To use it as a comparison to alleged asbestos exposure is misleading.

RJ Lee Group independently recalculated the task concentrations and included them in Table 6. After accounting for the cleavage fragments, the Ewing, et al task concentrations are generally consistent with those of Lees and Mlynarek.

B. Pinchin

Claimants' experts cite a demolition study performed by Pinchin Environmental (item 611 of Claimants' reliance documents) at a Canadian military base in Shilo, Manitoba. Building E12 was a one-story wood frame building with drywall ceilings and vermiculite attic insulation. Two simulations were performed: 1) a gross demolition of the ceiling drywall and subsequent dispersement of insulation; and 2) an abatement-style insulation removal. Air samples were collected and submitted for analysis using both PCM (NIOSH 7400) and TEM (NIOSH 7402).

Many of the PCM samples (Appendix II of the Pinchin report) were overloaded with dust and could not be analyzed. Those that could be analyzed show concentrations ranging from nondetect to as high as 18 f /cc (sample 77955).

Eight of the samples from the gross demolition testing were analyzed by TEM (Appendix III of the report). Though the report states the samples were analyzed using NIOSH 7402, numerous deviations from the protocol occurred. Each sample was prepared for TEM analysis using an indirect preparation procedure (as indicated by "Fraction Re-filtered:" on the data tables). On each sample, 10 grid openings were analyzed instead of the mandated 40. In addition to the fibers that must be counted by NIOSH 7402 (longer than 5 µm and wider than 0.25 µm), fibers shorter than 5 µm, as well as fibers longer than 5 µm but thinner than 0.25 µm were separately counted (page 5 of the report). Because of these deviations from the protocol, the data cannot be used for exposure assessment and must be considered as unreliable.

C. Grace Historical Testing

W. R. Grace conducted various attic simulations related to possible fiber exposure during installation of ZAI. Due to the artificial nature of the simulated attic testing location, the reported data can only be considered as an indication of the airborne fibers of all types. As noted by Yang[41], the principal method of analyzing these samples was an optical technique consistent with NIOSH 7400 (PCM). No attempt was made to perform a differential count to exclude nonasbestos fibers. Much of this data shows estimated airborne concentrations averaging 1 to 2 f/cc during the simulated attic tests. These data are consistent with those generated by Versar (and discussed above).

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41 Depositions of Julie C. Yang, Ph.D., in United States of America v. W. R. Grace & Co., et al., Civ. No. 01-72-M-DVM at pp. 156-158, 164-165 (Aug. 21, 2002), and In Re W. R. Grace & Co., et al., No. 01-01139 JFK at pp. 83-84 (Feb. 20, 2003).

As documented in both Claimants' and the Lees and Mylnarek study, only a small portion of PCM-sized fibers are asbestos fibers. The data shown in Table 5 indicate that the average reduction of worker task concentration, obtained by analyzing the samples for PCME amphibole particles instead of PCM fibers, is nearly 4-fold. When the PCME amphiboles are further discriminated to include just asbestos fibers (not cleavage fragments), there is more than a 24-fold reduction in concentration (PCM to PCME asbestos), on average. Thus, only about 6% of the PCM fibers are PCME asbestos.

This observation that not all fibers in the air are asbestos fibers is supported by a study performed by Wylie and Watson[42]. In their study, samples of vermiculite were agitated in a glove box to generate a known source of airborne particulate. The airborne particles were sampled and analyzed using PCM (7400) and TEM (7402). Wylie and Watson concluded:

> "The source of elongated particles counted by PCM are primarily vermiculite. The majority of the elongated vermiculite particles were plates with some scrolled tubes. An average of < 1.5% of elongated particles counted by PCM could be classified as asbestos."

This estimate of approximately 1.5% of the PCM fibers as asbestos compares favorably with the Lees and Mlynarek simulation estimate of 6%. Both values show that most of what is observed in the PCM is not asbestos, indicating the PCM procedure is not adequate for evaluating possible airborne vermiculite particles.

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42 A. Wylie and M. Watson (1994). "Airborne Fibers Generated From Vermiculite", June 20, 1994.

D. Dust Samples

Numerous samples of surface dust were collected by Claimants' experts in houses purportedly containing ZAI. Claimants' experts argue that their measurements are indicators of past airborne concentrations and indicators of future concentrations.

1. Surface Dust Concentrations are Not Predictors of Past or Future Exposures

Proponents of surface dust sampling often claim that the concentration of asbestos fibers found on a surface is a predictor of potential future airborne concentrations. There is no scientific basis for this claim. Studies have found that, even with surface dust concentrations in the millions of structures per square centimeter, airborne levels are barely measurable.

These proponents ignore the disaggregating effects of the indirect preparation procedure. They also ignore the tendency of asbestos to stick to surfaces, and the effects of moisture and other parameters on the tendency for surface dust to resist becoming entrained by a disturbance.

The potential for re-suspension of the surface dust is described by K-factors (in units of cm^{-1}), the ratio of airborne fiber concentration to the surface fiber concentration. Chatfield and Fowler[43] examined surface sampling to determine if there was a relationship between surface dust loadings and airborne concentrations. They concluded that current dust analytical procedures, while practical analytical tools, do not preserve the size distribution of the particles as they existed on the surface. Without the knowledge of the condition of the particles on the

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43 D. P. Fowler and E. J. Chatfield (1996). "Surface Sampling for Asbestos Risk Assessment", presented at Inhaled Particles VIII, August 26-30, 1996.

surface, it is impossible to determine k-factors. Chatfield reiterated this conclusion in a later paper[44] by saying "simple resuspension factor calculations using surface dust measurements ... do not provide a valid scientific basis for prediction" of airborne asbestos concentrations.

Other studies[45] have reached similar conclusions. Moreover, in a recent Daubert ruling, the federal bankruptcy court found "that dust results do not give an indication of what has been in the air, nor do they demonstrate release potential of asbestos-containing materials ..."[46].

2. Particles Found in Dust Samples were Primarily Cleavage Fragments.

In addition to being unreliable indicators of potential future airborne exposures, the dust sample results demonstrate that the vast majority of the particles in the dust are cleavage fragments. Table 6 summarizes the dust data from Claimants' testing and compares those reported results with the data after the TEM fiber sizes were evaluated to determine PCME concentrations. These fibers were then further analyzed to determine if they were asbestiform using the same algorithm as used for the EPA Phase 2 data. The data show there are very few PCME asbestos (risk) fibers in the dust data. As with the air data, 86% of the particles in the PCME size fraction are cleavage fragments and not asbestos.

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44 E. J. Chatfield (1999). "Correlated Measurements of Airborne Asbestos-Containing Particles and Surface Dust", in *Advances in Environmental Measurement Methods for Asbestos*, M. E. Beard and H. L. Rook, eds, American Society for Testing and Materials, publication STP 1342, p. 378 – 402.

45 R. J. Lee, D. R. Van Orden, and I. M. Stewart (1999). "Dust and Airborne Concentrations – Is There a Correlation?", Advances in Environmental Measurement Methods for Asbestos, ASTM publication STP 1342.

46 R. Newsome (2002). Findings of Fact and Conclusions of Law RE: Motions of the Debtors and Asbestos Property Damage Committee to Exclude Evidence, US Bankruptcy Court for the District of Delaware, In re: Armstrong World Industries, Inc. et al. Case No. 00-04471 (RJN).

VIII. Conclusions

Based on the above discussions, an extensive literature review, discussions with other experts, and personal knowledge of the ZAI mineralogy and analytical techniques, it can be concluded with a reasonable degree of scientific certainty that:

1) Phase Contrast Microscopy (PCM) measurements of airborne fiber concentrations in atmospheres where ZAI is being manipulated, handled, or removed by a homeowner significantly overestimate potential "*asbestos*" fiber concentrations. In Claimants' experts' airborne "*asbestos*" fiber counts, the average reduction would be more than three-fold, simply by excluding non-mineral fibers such as hair, cotton, and cellulose.

2) *Asbestos* is a commercial term applied to the occurrence (in sufficient quantity to make their extraction and beneficiation economically viable) of *asbestiform* minerals which are minerals with physical and thermal properties of potential commercial significance in applications requiring flexibility, thermal stability or high tensile strength. *Asbestiform* minerals are naturally formed in a fibrous, flexible form with a high aspect ratio known as fibers.

3) *Asbestos* minerals have non-asbestos analogs called *cleavage fragments*. When finely divided or crushed, *cleavage fragments* may have a similar appearance to asbestos fibers, but are generally thicker and shorter than asbestos fibers and have other distinguishing characteristics.

4) Regulatory methods are and have been expressly designed to measure the concentrations of asbestos fibers and explicitly cite the "asbestiform varieties of … [amphibole minerals]" in air, water, or bulk samples, not the concentration of cleavage fragments.

5) Claimants' experts misrepresent the OSHA position by failing to acknowledge that in 1992 OSHA explicitly excluded amphibole *cleavage fragments* from their asbestos regulations.

6) Claimants' experts' TEM analysis is flawed because they included non-asbestiform *cleavage fragments* in their "*asbestos*" count thereby inflating their "*asbestos*" results.

7) Contrary to Claimants' experts' assertions, the majority of the amphiboles in ZAI are neither asbestiform nor respirable.

8) Claimants' estimated concentrations would be reduced by at least ten-fold if the concentration of non-asbestiform *cleavage fragments* in their samples were excluded from their "*asbestos*" count.

9) Exposure measurements made by RJ Lee Group and two groups of Claimants' experts using PCM methodology and adjustied for the quantities of non-mineral fibers and *cleavage fragments*, indicate airborne asbestos concentrations would have been comparable to or below relevant standards.

10) Evaluation of Claimants' experts' own surface dust data demonstrates that their use of indirect preparation significantly breaks up the mineral particles in the

samples. The surface dust particles are smaller than the airborne particles thus demonstrating the disaggregating effect of indirect preparation.

11) Neither the ASTM surface dust method(s) nor the indirect preparation technique is generally accepted as a reliable indicator of past or potential future airborne exposures. Results derived from the analysis of samples prepared using an indirect preparation technique cannot be used for risk evaluation.

12) There is no reliable scientific evidence that ZAI is unsafe.

In addition to our own research and studies of asbestos, our opinions and testimony are based on the research and studies of other scientists and governmental bodies. A list of reliance materials on which we may rely to form the basis of our opinions is attached and incorporated by reference; however, we may also rely in whole or in part on the publications as well as opinions, data and materials produced in discovery, or contained in the reports of other experts which the plaintiffs or the defendant designates in this action. We also reserve the right to rely on any scientific articles or studies subsequently presented or published. We have prepared this report in accordance with Rule 26(a) (2) of the Federal Rules of Civil Procedure.

Richard J. Lee, PhD

Figures

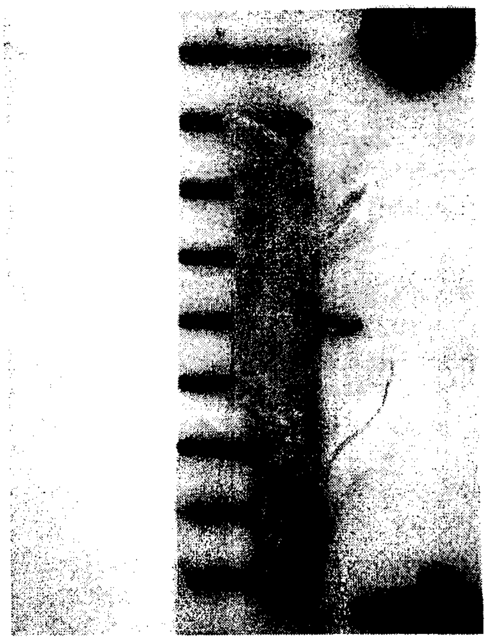


Figure 1a.

Figure 1b.

Figure 1. A) An optical photomicrograph of a bundle of amphibole asbestos prior to sonication. B) A TEM photomicrograph of the fibrils released from the bundle in figure 1 after 3 minutes of sonication. The average diameter of the fibrils is more than a thousand fold less than the original bundle.

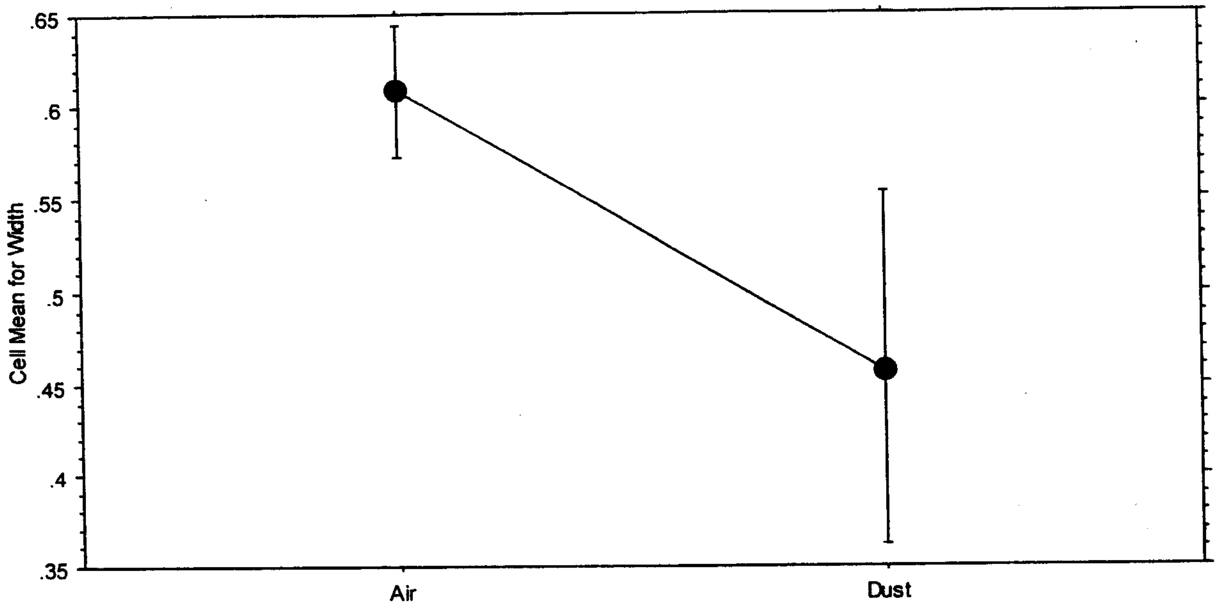


Figure 2. Comparison of the average diameter and 95% confidence interval of the diameters of airborne fibers with the same parameters for fibers found in the dust samples in Claimants' studies. The diameter of the dust particles has been reduced to such an extent that the two distributions are statistically different.

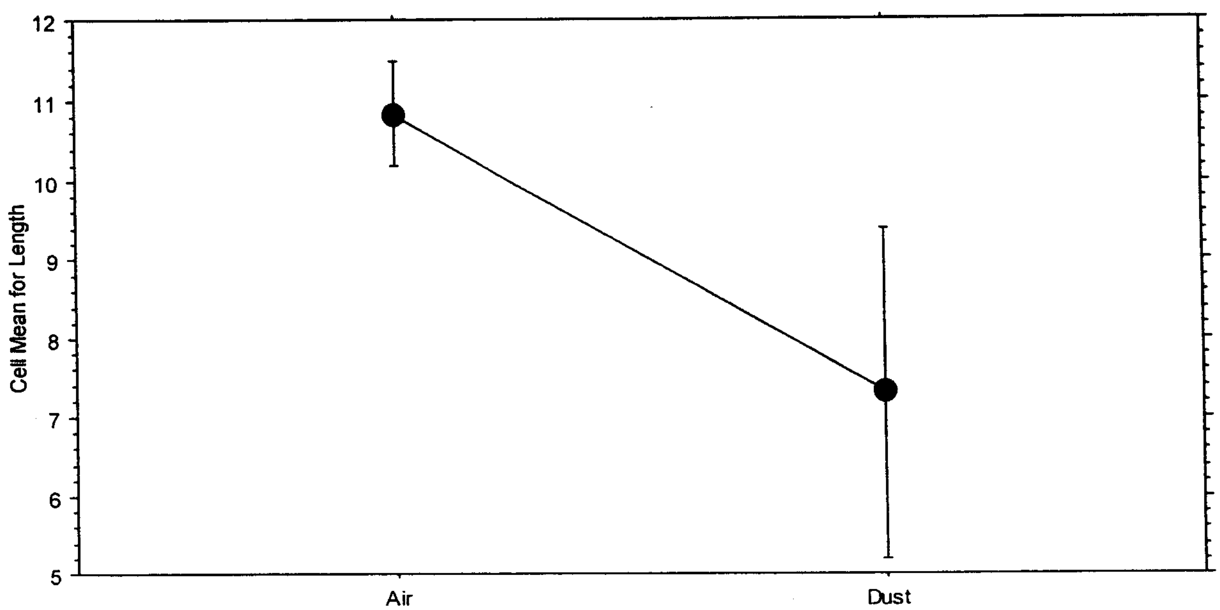


Figure 3. Comparison of the average length and 95% confidence interval of the lengths of airborne fibers with the same parameters for fibers found in the dust samples in Claimants' studies. The length of the dust particles has been reduced to such an extent that the two distributions are statistically different.

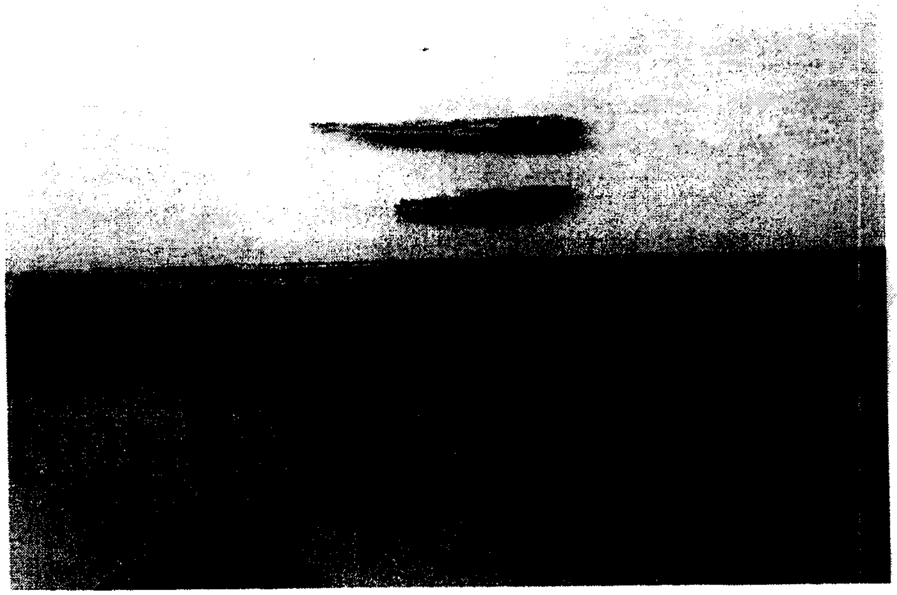


Figure 4a. Typical acicular fragments extracted from ZAI. The particles are typically 5-10 millimeters in length and 1-2 millimeters in diameter.

Figure 4b. Typical equant cleavage fragment observed in ZAI. Particles of this type dominate the amphibole fraction of the product.

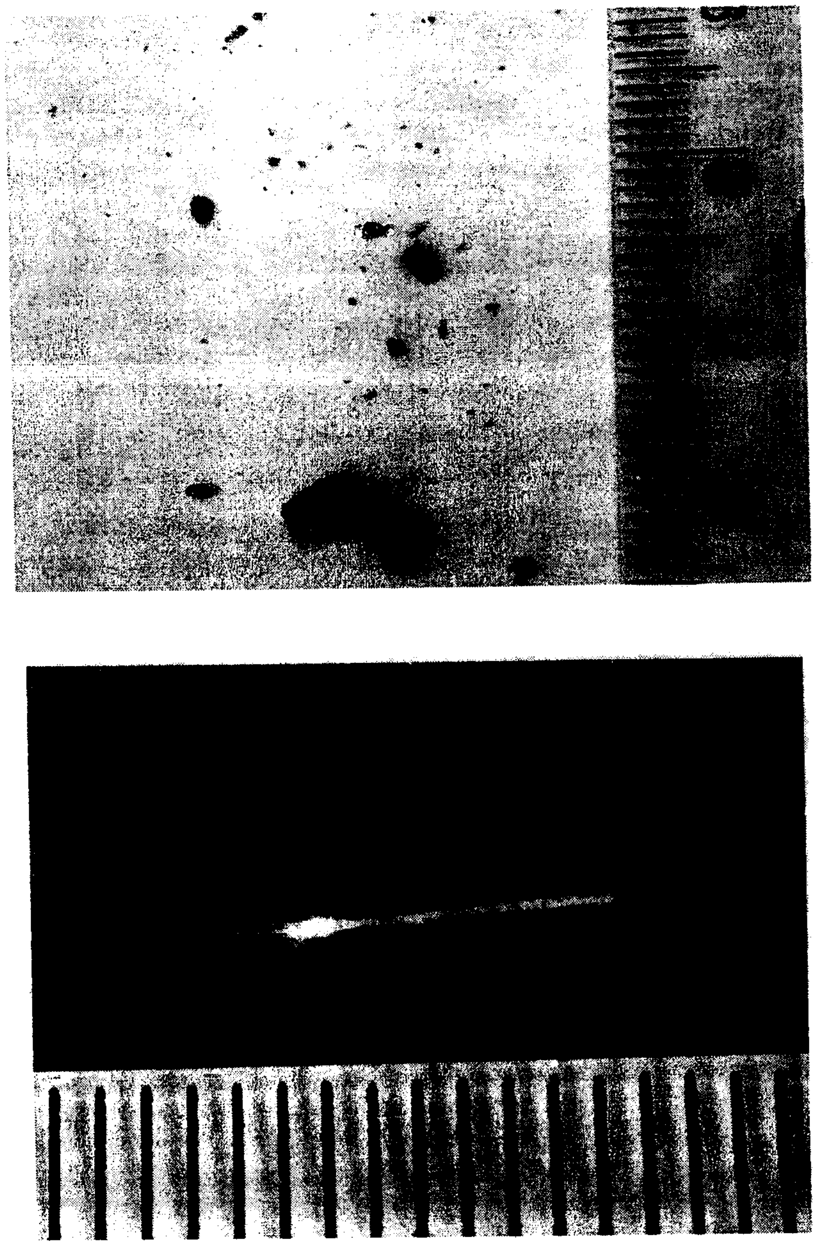
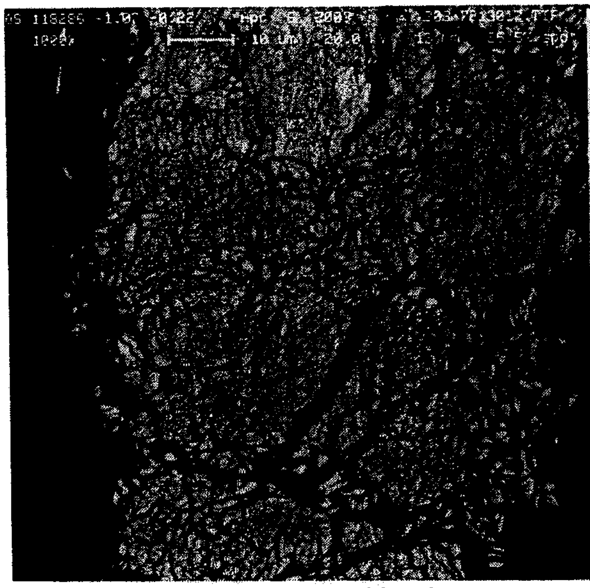
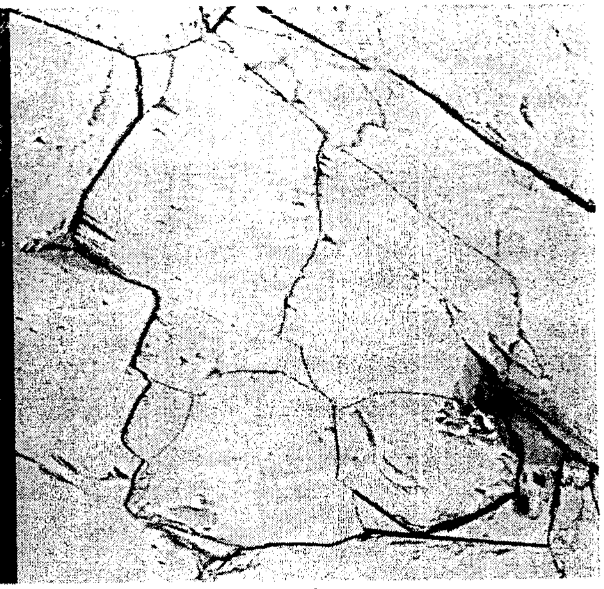


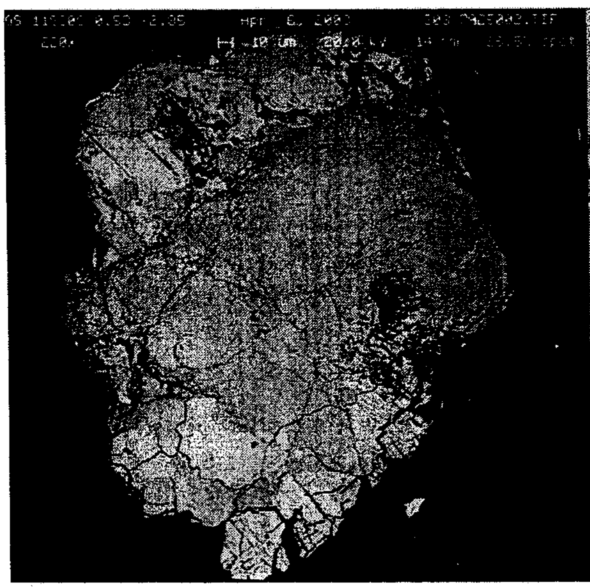
Figure 5. Comparison of broken pieces of an amphibole particle from ZAI (top, particle from Figure 4b) with tremolite asbestos fibers from Jamestown, California (bottom). As seen in the photomicrographs, the aspect ratio and shape of the particles is fundamentally different.



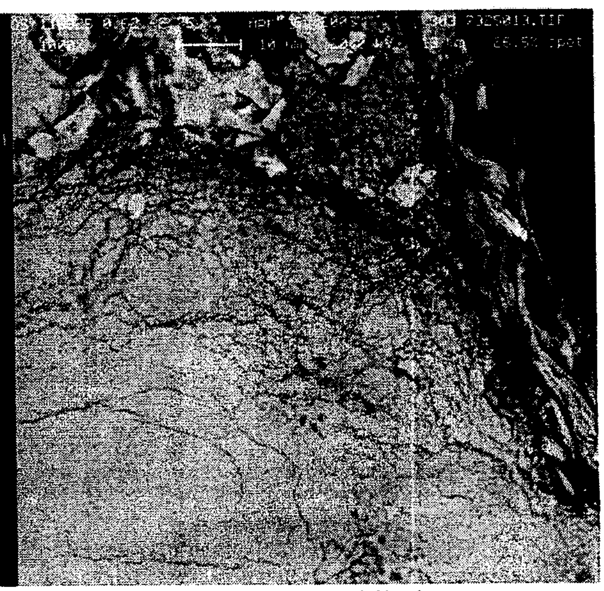
Jamestown, California



Shinness



ZAI Amphibole



ZAI Amphibole

Figure 6. SEM photomicrographs of a polished cross-section of Tremolite asbestos from Jamestown, Shinness, and ZAI. The length of the fibers are perpendicular to the photograph. The typical fibril diameter in the Jamestown tremolite is less than 0.5 micrometer. Note the coarse crystal structure in the Shinness tremolite, well-defined crystal boundaries and smooth features compared to the asbestos tremolite from Jamestown. The ZAI material has characteristics intermediate between the Shinness and Jamestown tremolites. The majority of the material is typical cleavage fragments, bounded by finer crystals generally larger the 1.0 micrometer that exhibit characteristic cleavage faces.

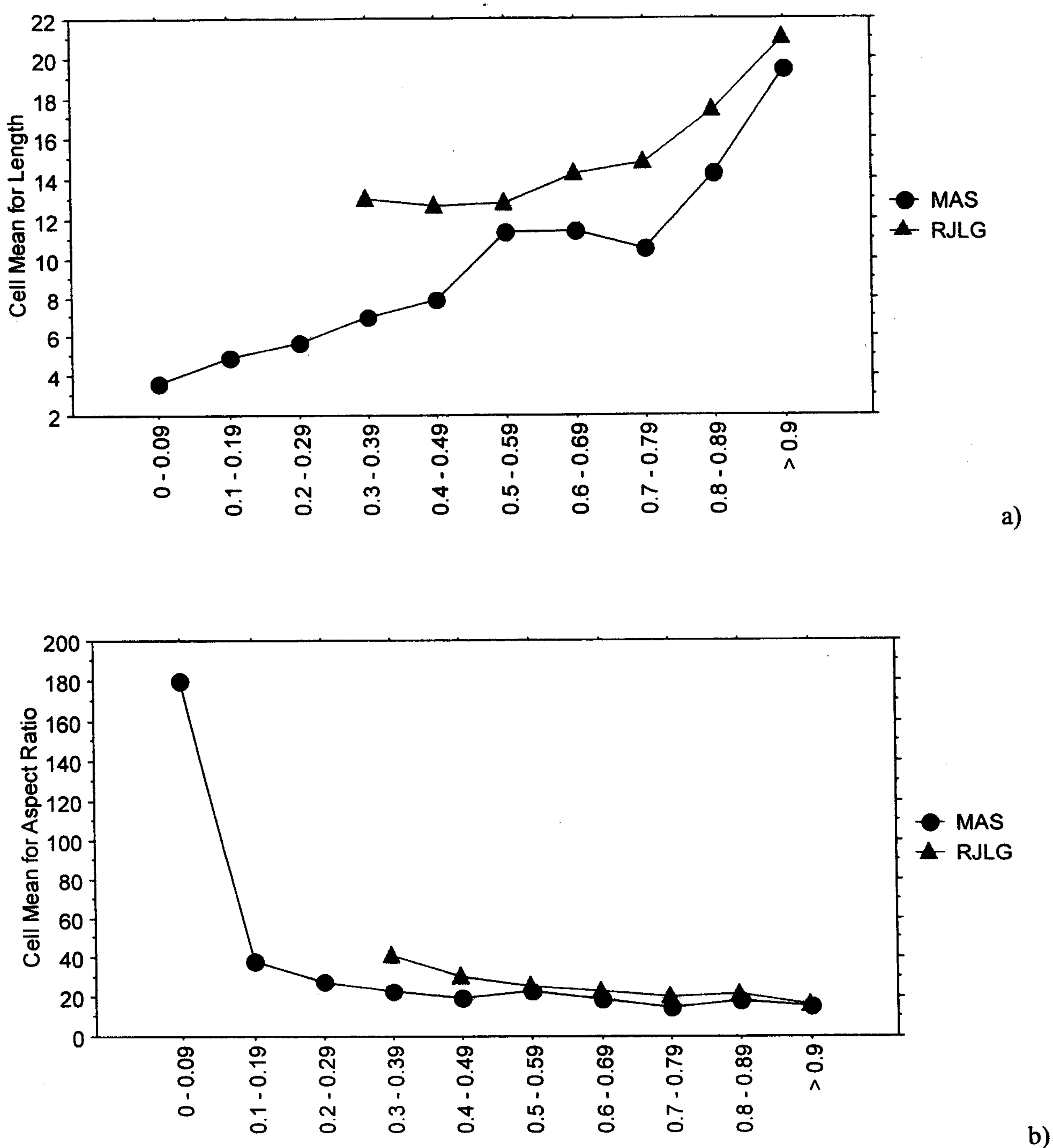


Figure 7. Comparison of the aspect ratio and length distribution obtained by MAS and RJLG in simulations of the disturbance of ZAI. A) Mean aspect ratio for fibers in each width class. B) Mean length for fibers in each width class. The distributions are very similar, and totally different than the distributions obtained for the dust samples prepared by indirect preparation.

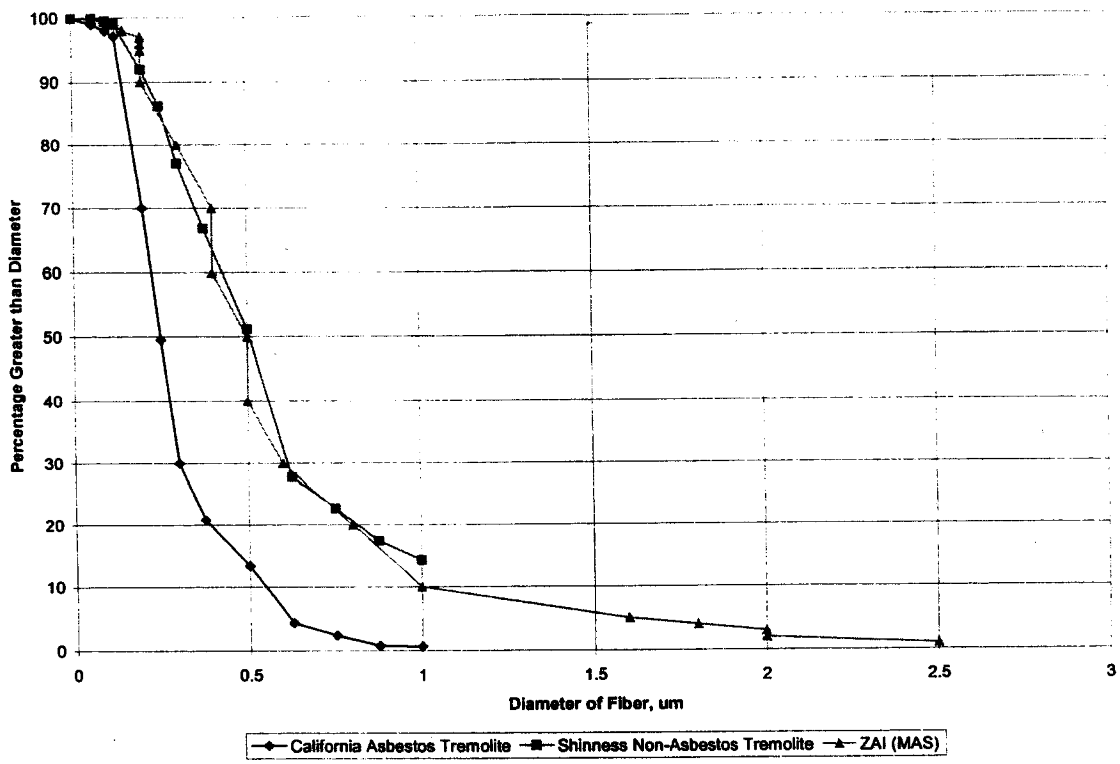


Figure 8. Comparison of the width distribution of amphibole particles observed by MAS with those reported for two reference tremolite standards (Davis, et al.). The amphibole diameter distribution reported for the ZAI amphibole is the same as that of the Shinness tremolite (a mineral shown to have no biological activity in animal injection studies).

Tables

Table 1. Excerpts from Selected References Describing Cleavage Fragments

Reference	Description
Michael E. Beard, EPA Chemist letter to Sally A Sasnett, dated November 3, 1992[T1-1]	Many samples of non-asbestos cleavage fragments have been mistakenly labeled as asbestos. Note that cleavage fragments defined in table 1-1 of the EPA Interim Method (EPA-600/M4-82-020) are not asbestos.
W.J. Campbell, "Identification of Selected Silicate Minerals and their Asbestiform Varieties," NBS Special Publication 506, November 1978 [T1-2].	The problem of asbestiform particulates with its environmental and health implications has been compounded by the lack of precision with which the term 'asbestos' has been used. In many instances, non-asbestiform mineral particles have been identified as microscopic fibers of asbestos-related minerals.
W.J. Campbell et al. "Relationship of Mineral Habit to Size Characteristics for Tremolite Cleavage Fragments and Fibers," Bureau of Mines Report of Investigations RI-8367, (1979) [T1-3]	Asbestos materials of commercial importance have the following characteristics: Aspect ratios ranging upward to 1000:1 or higher, Very thin fibrils, generally less than 0.5μm in width, Very high flexibility and tensile strength compared to nonasbestos minerals. Parallel fiber growth in veins.
W.J. Campbell et al, "Selected Silicate Minerals and Their Asbestiform Varieties, Mineralogic Definitions and Identification – Characterization," Dept. of Interior, Bureau of Mines, Information Circular 8751, (1977) [T1-4]	Cleavage Fragments: A fragment produced by breaking crystals in directions related to the crystal structure and always parallel to possible crystal faces…Amphiboles with prismatic cleavage will produce prismatic cleavage fragments. These fragments resemble fibers. However, because they did not grow as fibers, they cannot have the characteristics of fibers. The EPA Interim Method and the Improved Method define cleavage fragments as particles having aspect ratios less than 10:1 (length to width). Cleavage fragments are not regulated by EPA or OSHA.
Jean Dolensek, "Symposium to Revisit Taconite Tailings," The Minnesota Prospector, January 2003 [T1-5]	Asbestiform Mineral – Aspect ratio increases as particles get longer. Mineral Cleavage Fragment – Aspect ratio remains constant and is independent of length.
C-Y Hwang, "Size and Shape of Airborne Asbestos Fibers in Mines and Mills," British Journal of Industrial Medicine, 1983; V40: 273-279 [T1-6]	True diameter and true length distributions of airborne fibers in the various stages of fiber processing were non Gaussian. Differences between manufacturing stages were considerably less than between asbestos types.
Ed Ilgren: "Expert Report re WR Grace – Related Attic Insulation Asbestos Litigation – The Biological Relevance of Tremolite Cleavage Fragments: April 10,2003 [T1-7]	Cleavage fragments have fundamentally different properties from asbestos fibers that are biologically relevant. Cleavage fragments lack the strength, durability, flexibility and acid resistance of asbestos. They are therefore unable to persist in the body in a manner similar to asbestos. Scientific evidence demonstrates that cleavage fragments are noncarcinogenic in animals and humans.

Table 1. Excerpts from Selected References Describing Cleavage Fragments, continued.

<table>
<tr><th>Reference</th><th>Description</th></tr>
<tr><td>A.M. Langer, R.P. Nolan and J. Addison, "Distinguishing between Amphibole Asbestos Fibers and Elongated Cleavage Fragments of Their Non-Asbestos Analogues" <u>Mechanisms in Fibre Carcinogenisis</u>, Edited by R.C. Brown et al., Plenum Press, New York, 1991 [T1-8]</td><td>Problems Emerging as the Result of Definitions.
<table>
<tr><th>PLM Property</th><th>Tremolite Asbestos</th><th>Tremolite Cleavage Fragment</th></tr>
<tr><td>Optical Level</td><td>Polyfilamentous;curvilinear Splayed ends, near parallel Extinction.</td><td>Optically continuous single Fragment; angular extinction Amphibole cleavage</td></tr>
<tr><td>Aspect Ratio</td><td>Avg =10.9:1, >20:1 , 18%.</td><td>Avg.=3.7:1, >20:1, 0%.</td></tr>
<tr><td>TEM Property</td><td></td><td></td></tr>
<tr><td>Sublight level</td><td>Parallel sides to fiber</td><td>Irregular stepped sides</td></tr>
<tr><td>Structure</td><td>Twins (100) Frequent</td><td>Twins rare</td></tr>
<tr><td>SAED</td><td>(001)x(010), (001)x(100), (103)x(010), No Kikuchi lines</td><td>(110)x(TTT), (020)x(TTT), (131)x(TTT), Kikuchi lines common</td></tr>
</table></td></tr>
<tr><td>MSHA Asbestos Hearing Panel: Public Meeting on Asbestos Charlottesville, VA June 20,2002 [T1-9]</td><td>P119 Ann Wylie: Cleavage fragments get wider as they get longer whereas for asbestos fibers width is essentially independent of length. Unit fibrils are the basic building block of asbestos; widths are constant and independent. Populations of fibers have very distinctive characteristics. Either half the population is longer than 10μm, or less than 0.5μm, or they have high aspect ratios.
P177 Rich Lee: The Libby data clearly illustrate that there is an asbestiform and nonasbestiform population in that airborne population.</td></tr>
<tr><td>OSHA, "Regulations (Preambles to Final Rules) IV. Mineralogical Considerations." (1992) [T1-10]</td><td>P6 "Amphibole asbestos populations are characterized by aspect ratios > 20:1." "Asbestos crystallizes in a fluid medium; growth takes place rapidly in one direction." "Because their origin is different, populations of fibers and cleavage fragments of the same mineral are different.
P7 "Because of the nature of asbestos, width changes very little as length increases.
P9 Due to the straight line fibrillar crystal growth of asbestos, the width of an asbestos fiber is essentially independent of its length. In contrast cleavage fragment populations show increasing width as particle length increases due to normal 3 dimensional crystal growth.</td></tr>
<tr><td>National Research Council, "Asbestiform Fibers – Nonoccupational Health Risks," 1984 [T1-11]</td><td>P33 One of the properties shared by high quality fibers of asbestos, whiskers, and glass is their diameter-dependent strength. That is, the strength of the fibers per unit of cross-sectional area increases as the diameter decreases. Thus, the smaller the diameter of the fibers, the greater the strength.
P38 The relatively high flexibility of the asbestiform fibers enables them to bend without breaking and may facilitate their passage through the respiratory tract. The exceptional physicochemical durability of asbestiform fibers is one of the basic requirements for their biological effects.</td></tr>
</table>

Table 1. Excerpts from Selected References Describing Cleavage Fragments, continued.

Reference	Description
R.L. Perkins and B.W. Harvey, "Method for the Determination of Asbestos in Bulk Building Materials," [Improved Method] EPA/600/R-93-116, July 1993 [T1-12]	Asbestos: A commercial term applied to the asbestiform varieties of six different minerals…The properties of asbestos that made it commercially useful are its (1) ability to be separated into long, thin, flexible fibers, (2) high tensile strength, (3) low thermal and electrical conductivity, (4) high mechanical and chemical stability, and (5) high heat resistance. These fibers are classified as carcinogens and are regulated by EPA and OSHA.
E.J.W. Whittaker, "Mineralogy, Chemistry and Crystallography of Amphibole Asbestos," Mineralogical Association of Canada, Short Course in Mineralogical Techniques of Asbestos Determination, Editor R.L. Ledoux, 1979 [T1-13]	P30, Fibrous material will approach its theoretical strength if the adhesion across the fibrous cleavage is less than 20-30% of the cohesion of the material…Appropriate nucleation conditions so as to produce many fine fibrils…such as occur in cross-fiber veins permit inherent strength of silicate chain to be manifested in macroscopic properties.
A.G. Wylie, "The Habit of Asbestiform Amphiboles: Implications for the Analysis of Bulk Samples," from Advances in Environmental Measurement Methods for Asbestos, Michael E. Beard and Harry L. Brooks, Editors, ASTM STP 1342 [T1-14]	The Analysis of Bulk Samples, p60. Population of fibers > 5µm w/ 1) aspect ratios >20:1, 2) bundles w/ splayed ends, 3) fiber width < 0.5µm, 4) curved fibers.
A.G. Wylie, "Modeling Asbestos Populations: A Fractal Approach," Canadian Mineralogist, Vol. 30, p437-446 (1993) [T1-15]	Different types of asbestos have different resistances to fragmentation.
Ann G. Wylie, Robert L. Virta and Estelle Russek, "Characterizing and Discriminating Airborne Amphibole Cleavage Fragments and Amosite Fibers: Implications for NIOSH Method." American Industrial Hygiene Association Journal (46) April 1985 [T1-16].	Percentage of Amphibole Cleavage Fragments and Amosite Asbestos Fibers that conform to several dimensional criteria (table below)

Percent of Total Particles

Length and Aspect Ratio	Width	Clev Frag %	Amosite %
Length≥ 5µm Aspect Ratio ≥ 3	All widths w≥0.25µm 3µm≥w≥0.25µm	41 41 39	64 50 50
Length≥ 5µm Aspect Ratio ≥ 10	All widths w≥0.25µm 3µm≥w≥0.25µm	6 6 6	57 43 43
Length≥ 5µm Aspect Ratio ≥ 20	All widths w≥0.25µm 3µm≥w≥0.25µm	1 1 1	41 27 27
Length≥ 10µm	w≤0.25µm	0	5
Length≥ 5µm	w≤0.5µm	2	42
Length≥ 8µm	w≤0.25µm	0	7

Table 1. Excerpts from Selected References Describing Cleavage Fragments, continued.

Reference	Description
T. Zoltai, "Amphibole Asbestos Mineralogy," Amphiboles and Other Hydrous Pyriboles – Mineralogy, D.R. Veblin editor, Reviews in Mineralogy, Volume 9a, MSA 1981 [T1-17].	P238 The strength of well-developed asbestiform fibers may be as much as 50 times higher than that of single crystals of the same material. P246 Fibers are extremely strong and flexible, while acicular cleavage fragments are weak and brittle. P272 Fibers appear to gain exceptional strength from their surface structures, which are different than their internal structure. The unusual unidirectional growth of the fibers produces continuous and consistent parallel surfaces.
Jack Zussman, "The Crystal Structures of Amphibole and Serpentine Minerals," NBS Special Publication 506, November 1978 [T1-18]	P39 The process of stripping fibrils from asbestos is likely to be one of breaking crystallites away from the aggregate at the grain boundaries (between crystallites which are lined up parallel to the fiber axis) across which there is weak cohesion.

Table 2. List of Citations from Relevant Regulations and Analytical Methods

TITLE	REFERENCE	CITED PASSAGE
Regulations, Preambles to Final Rules OSHA	Intro to 29 CFR Parts 1910 and 1926, Occupational Exposure to Asbestos, Tremolite, Anthophyllite and Actinolite (1 of 2) [T2-1]	"amends the revised asbestos standards (29 CFR Sections 1910.1001 and 1026.58) to remove non-asbestiform tremolite, anthophyllite and actinolite from their scope"
Regulations, Preambles to Final Rules OSHA	Introduction (1 of 4) [T2-2]	"...discusses OSHA's decision to remove non-asbestiform tremolite, anthophyllite, and actinolite (herein referred to as ATA..."
Regulations, Preambles to Final Rules OSHA	Introduction (1 of 4) [T2-3]	"OSHA is also removing and reserving 29 CFR 1910.1101, which designated 'Asbestos' and which has been applied to non-asbestiform ATA during the administrative stay..."
Regulations, Preambles to Final Rules OSHA	Introduction (1 of 4) [T2-4]	"Asbestos and non-asbestiform ATA appear to be distinguishable mineral entities on a population basis, and in most instances on a particle basis"
Regulations, Preambles to Final Rules OSHA	Introduction (3 of 4) [T2-5]	"Thus, OSHA does not believe that potential asbestos contamination of non-asbestos minerals, including non-asbestiform ATA, is sufficient reason to include such non-asbestiform minerals in the asbestos standard"
Regulations, Preambles to Final Rules OSHA	Introduction (3 of 4) [T2-6]	"If an identification error is made, it is likely to be a false positive for asbestos rather than a false negative"
Regulations, Preambles to Final Rules OSHA	Pertinent Legal Authority (3 of 4) [T2-7]	"Thus, the primary basis for including the non-asbestiform varieties of ATA in OSHA's asbestos standards was the Agency's belief that fiber populations with similar 'index' fiber counts, presented essentially the same risk, regardless of whether those 'index' fibers were strictly asbestos in the mineralogical sense"
Regulations, Preambles to Final Rules OSHA	Pertinent Legal Authority (3 of 4) [T2-8]	"OSHA believed that the primary determinant of biological activity of asbestos is fiber dimension, and that varieties of asbestos minerals of relevant dimension have the same carcinogenic and fibrogenic potential per fiber"
Regulations, Preambles to Final Rules OSHA	Regulatory History (1 of 4) [T2-9]	"...petitioned OSHA to restrict the application of the 1972 standard so that non-asbestiform anthophyllite and tremolite would not be covered by it. In October 1974 OSHA interpreted the applicability of the asbestos standard to mean only asbestiform tremolite with and aspect ratio of 5 to 1"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Regulations, Preambles to Final Rules OSHA	Regulatory History (2 of 4) [T2-10]	"In its supplemental proposed rule (49 FR 11416, April 10, 1984)...which regulated only mineralogically correct 'asbestos'"
Regulations, Preambles to Final Rules OSHA	Mineralogical Considerations (2 of 8) [T2-11]	"Asbestiform is a mineralogical term describing a particular mineral habit. The habit of a mineral is the shape or form a crystal or aggregate of crystals take on during crystallization and is dependent on the existing environmental/geological conditions at the time of formation"
Regulations, Preambles to Final Rules OSHA	Mineralogical Considerations (2 of 8) [T2-12]	"The term asbestiform is a mineralogical term used to refer to those minerals which are found in a particular mineral habit. That is, while all asbestos is asbestiform, not all asbestiform minerals are asbestos"
Regulations, Preambles to Final Rules OSHA	Mineralogical Considerations (5 of 8) [T2-13]	"...the width of an asbestos fiber is essentially independent of its length and is not easily altered by processing. In contrast, cleavage fragment populations show increasing width as particle length increases due to the characteristics imparted from normal three dimensional crystal growth"
Regulations, Preambles to Final Rules OSHA	Mineralogical Considerations (5 of 8) [T2-14]	"Thus OSHA believes that while one can differentiate between mineral types when populations of particles are examined, when single, isolated particles are examined (e.g. particles from air samples) the ability to differentiate may become more difficult"
Regulations, Preambles to Final Rules OSHA	Mineralogical Considerations (8 of 8) [T2-15]	"Thus although the Agency now reaches a different conclusion than it did in 1986 concerning the evidence of health risks of non-asbestiform ATA, it continues to believe that the mineralogical forms are sufficiently distinctive to be treated differently for regulatory purposes. Also, unlike its determination in 1986, which was based on a far less extensive review of health effects evidence, the Agency now finds that differences in biologic effect between asbestos and its non-asbestiform analogues are likely related to the distinctions which define the two groups as separate mineral entities"
Regulations, Preambles to Final Rules OSHA	Health Effects (9 of 10) [T2-16]	"...OSHA reaffirms its preliminary determination in the proposal that there is insufficient evidence to conclude that non-asbestiform ATA present a health risk similar in kind and magnitude to that of their asbestiform counterparts"
Regulations, Standards - 29 CFR	Asbestos - 1910.1001(b) Definitions (1 of 31) [T2-17]	"'Asbestos' includes chrysotile, amosite, crocidolite, tremolite asbestos, anthophyllite asbestos, actinolite asbestos, and any of these minerals that have been chemically treated and/or altered"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Regulations, Standards - 29 CFR	Asbestos - 1910.1001(b) Definitions (2 of 31) [T2-18]	"'Fiber' means a particulate form of asbestos 5 micrometers or longer, with a length-to-diameter ratio of at least 3 to 1"
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (2 of 17) [T2-19]	"Asbestos: A term for naturally occurring fibrous minerals. Asbestos includes chrysotile, crocidolite, amosite (cummingtonite-grunerite asbestos), tremolite asbestos, actinolite asbestos, anthophyllite asbestos, and any of these minerals that have been chemically treated and/or altered. The precise chemical formulation of each species will vary with the location from which it was mined. Nominal compositions are listed:
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (2 of 17) [T2-20]	"Asbestos Fiber: A fiber of asbestos which meets the criteria specified below for a fiber"
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (2 of 17) [T2-21]	"Cleavage Fragments: Mineral particles formed by comminution of minerals, especially those characterized by parallel sides and a moderate aspect ratio (usually less than 20:1)"
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (2 of 17) [T2-22]	"Fiber: A particle that is 5 um or longer, with a length-to-width ratio of 3 to 1 or longer"
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (3 of 17) [T2-23]	"...PCM does not positively identify asbestos fibers...Positive identification of asbestos must be performed by polarized light or electron microscopy techniques"
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (11 of 17) [T2-24]	"(5) Count only fibers equal to or longer than 5 um. Measure the length of curved fibers along the curve"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Regulations, Standards - 29 CFR	Detailed procedure for asbestos sampling and analysis - Non-Mandatory - 1910.1001 App B (11 of 17) [T2-25]	"Alternate differential counting techniques should be used if discrimination is desirable. Differential counting may include primary discrimination based on morphology, polarized light analysis of fibers, or modification of PCM data by Scanning Electron or Transmission Electron Microscopy"
Asbestos in Air	OSHA Method ID-160 (Intro 1 of 15) [T2-26]	"Asbestos: A term for naturally occurring fibrous minerals. Asbestos includes chrysotile, crocidolite, amosite (cummingtonite-grunerite asbestos), tremolite asbestos, actinolite asbestos, anthophyllite asbestos, and any of these minerals that have been chemically treated and/or altered. The precise chemical formulation of each species will vary with the location from which it was mined"
Asbestos in Air	OSHA Method ID-160 (Intro 2 of 15) [T2-27]	"Asbestos Fiber: A fiber of asbestos which meets the criteria specified below for a fiber"
Asbestos in Air	OSHA Method ID-160 (Intro 2 of 15) [T2-28]	"Aspect Ratio: The ratio of the length of a fiber to it's diameter (e.g. 3:1, 5:1 aspect ratios)"
Asbestos in Air	OSHA Method ID-160 (Intro 2 of 15) [T2-29]	"Cleavage Fragments: Mineral particles formed by comminution of minerals, especially those characterized by parallel sides and a moderate aspect ratio (usually less than 20:1)"
Asbestos in Air	OSHA Method ID-160 (Intro 2 of 15) [T2-30]	"Fiber: A particle that is 5 um or longer, with a length-to-width ratio of 3 to 1 or longer"
Asbestos in Air	OSHA Method ID-160 (Intro 2 of 15) [T2-31]	"Tremolite, Anthophyllite, and Actinolite: The non-asbestos form of these minerals which meet the definition of a fiber. It includes any of these minerals that have been chemically treated and/or altered"
Asbestos in Air	OSHA Method ID-160 (1.3 pg 2 of 15) [T2-32]	"The main disadvantage of PCM is that it does not positively identify asbestos fibers. Other fibers which are not asbestos may be included in the count unless differential counting is performed"
Asbestos in Air	OSHA Method ID-160 (1.5 pg 3 of 15) [T2-33]	"Asbestos fiber possesses a high tensile strength along its axis, is chemically inert, non-combustible, and heat resistant. It has high electrical resistance and good sound absorbing properties. It can be weaved into cables, fabrics or other textiles, and also matted into asbestos papers, felts, or mats"
Asbestos in Air	OSHA Method ID-160 (6.7 pg 8 of 15) [T2-34]	"As previously mentioned in Sect. 1.3, PCM does not provide positive confirmation of asbestos fibers. Alternate differential counting techniques should be used if discrimination is desirable. Differential counting may include primary discrimination based on morphology, polarized light analysis of fibers, or modification of PCM data by Scanning Electron or Transmission Electron Microscopy"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (Intro 1 of 17) [T2-35]	"Asbestos: A term for naturally occurring fibrous minerals. Asbestos includes chrysotile, crocidolite, amosite (cummingtonite-grunerite asbestos), tremolite asbestos, actinolite asbestos, anthophyllite asbestos, and any of these minerals that have been chemically been treated or altered. The precise chemical formulation of each species varies with the location from which it was mined"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (Intro 2 of 17) [T2-36]	"Asbestos Fiber: A fiber of asbestos which meets the criteria specified below for a fiber"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (Intro 2 of 17) [T2-37]	"Cleavage Fragments: Mineral particles formed by comminution of minerals, especially those characterized by parallel sides and a moderate aspect ratio"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (Intro 2 of 17) [T2-38]	"Differential Counting: The term applied to the practice of excluding certain kinds of fibers from a phase contrast asbestos count because they are not asbestos"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (Intro 2 of 17) [T2-39]	"Fiber: A particle that is 5 um or longer, with a length-to-width ratio of 3 to 1 or longer. This may include cleavage fragments"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (1.5 pg 4 of 17) [T2-40]	"Asbestos minerals belong to two mineral families: the serpentines and the amphiboles. In the serpentine family, the only common fibrous mineral is chrysotile. Occasionally, the mineral antigorite occurs in a fibril habit with morphology similar to the amphiboles. The amphibole minerals consist of a score of different minerals of which only five are regulated by federal standard: amosite, crocidolite, anthophyllite asbestos, tremolite asbestos and actinolite asbestos. These are the only amphibole minerals that have been commercially exploited for their fibrous properties; however, the rest can and do occur occasionally in asbestiform habit"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (1.7 pg 5 of 17) [T2-41]	"Compared to cleavage fragments of the same minerals, asbestiform fibers possess a high tensile strength along the fiber axis"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (3.5 pg 10 of 17) [T2-42]	"For the purpose of regulation, the mineral must be one of the six minerals covered and must be in the asbestos growth habit...Observation of many fibers is often necessary to determine whether a sample consists of 'cleavage fragments' or of asbestos fibers"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (3.5 pg 10 of 17) [T2-43]	"Most cleavage fragments of the asbestos minerals are easily distinguishable from true asbestos fibers. This is because true cleavage fragments usually have larger diameters than 1um"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (3.5 pg 10 of 17) [T2-44]	"Where the particles are less than 1 um in diameter and have an aspect ratio greater than or equal to 3:1, it is recommended that the sample be analyzed by SEM or TEM if there is any question whether the fibers are cleavage fragments or asbestiform particles"
Regulations, Standards - 29 CFR	Polarized Light Microscopy of Asbestos--Non-Mandatory - 1910.1001 App J (3.5 pg 11 of 17) [T2-45]	"True asbestos fibers usually have 0 degrees extinction or ambiguous extinction, while cleavage fragments have more definite extinction"
Electronic Code of Federal Regulations	"Subpart M - National Emission Standard for Asbestos, 40 CFR 61.141" (2 of 5) [T2-46]	"...ACM is defined ...as any material containing more than one percent (1%) asbestos as determined using the method specified in App A, Sub F, 40 CFR Part 763 Sect. 1, Polarized Light Microscopy (PLM)"
Electronic Code of Federal Regulations	"Subpart M - National Emission Standard for Asbestos, 40 CFR 61.141" (2 of 5) [T2-47]	"...ACM is any asbestos-containing packing, gasket, resilient floor covering or asphalt roofing product which contains more than one percent (1%) asbestos as determined using polarized light microscopy (PLM) according to the method specified in App A, Sub. F, 40 CFR Part 763 (Sect. 61.141)"
Electronic Code of Federal Regulations	Toxic Substance Control Act Regulations 40 CFR Part 763 Ch 1 (763.83 pg 1 of 5) [T2-48]	"Asbestos means the asbestiform varieties of: chrysotile (serpentine); crocidolite (riebeckite); amosite (cummingtonite-grunerite); anthophyllite; tremolite; and actinolite"
Electronic Code of Federal Regulations	NESHAP Regulations, 40 CFR Part 61, Ch 1 (61.141 pg 1 of 5) [T2-49]	"Asbestos means the asbestiform varieties of serpentinite (chrysotile), riebeckite (crocidolite), cummingtonite-grunerite, anthophyllite, and actinolite-tremolite"
Electronic Code of Federal Regulations	"Interim Method of the Determination of Asbestos in Bulk Insulation Samples," 40 CFR Part 763, Ch 1, App E, Sub. E (1.1 pg 1 of 24) [T2-50]	"This method is applicable to all bulk samples of friable insulation materials submitted for identification and quantitation of asbestos components"
Electronic Code of Federal Regulations	"Interim Method of the Determination of Asbestos in Bulk Insulation Samples," 40 CFR Part 763, Ch 1, App E, Sub. E (1.7.2.2 pg 4 of 24) [T2-51]	"These procedures are not recommended for samples that contain amphibole minerals or vermiculite. Grinding of amphiboles may result in the separation of fiber bundles or the production of cleavage fragments with aspect ratios greater than 3:1. Grinding of vermiculite may also produce fragments with aspect ratios greater than 3:1"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
Electronic Code of Federal Regulations	"Interim Method of the Determination of Asbestos in Bulk Insulation Samples," 40 CFR Part 763, Ch 1, App E, Sub. E (1.7.2.3 pg 5 of 24) [T2-52]	"Table 1-1 lists the above properties for commercial asbestos fibers: Chrysotile (asbestiform serpentine; Amosite (asbestiform grunerite); Crocidolite (asbestiform Riebeckite); Anthophyllite-asbestos; Tremolite-actinolite-asbestos"
Electronic Code of Federal Regulations	"Interim Method of the Determination of Asbestos in Bulk Insulation Samples," 40 CFR Part 763, Ch 1, App E, Sub. E (9 of 24) [T2-53]	Table 2-1 Asbestos Minerals and Their Nonasbestiform Analogs - Asbestiform: Serpentine (Chrysotile), Amphibole (Anthophyllite asbestos, Cummongtonite-grunerite [Amosite], Crocidolite, Tremolite asbestos, Actinolite asbestos)
US Mine Safety and Health Administration	"Exposure Limits for Airborne Contaminants," 30 CFR 57.5001 (1 of 1) [T2-54]	"(b) The 8-hour time-weighted average airborne concentration of asbestos dust to which employees are exceed 2 fibers per milliliter greater than 5 microns in length, as determined by the membrane filter method magnification (4 millimeter objective) phase contrast illumination...'asbestos' as used herein is limited to the following chrysotile, amosite, crocidolite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos"
Consumer Product Saftey Commission	Definition section of CPSC Regulation, 16 CFR 1304.3 (pg 381) [T2-55]	"(b) Asbestos means a group of mineral fibers composed of hydrated silicates, oxygen, hydrogen, and other elements such as sodium, iron, magnesium, and calcium in diverse combinations and are: amosite, chrysotile, crocidolite, anthophyllite asbestos, actinolite asbestos, and tremolite asbestos"
NIOSH Manual of Analytical Methods	"Asbestos and Other Fibers by PCM," NIOSH Method 7400 (Measurement 19, Note 2 pg 7 of 15) [T2-56]	"Although some experienced counters are capable of selectively counting only fibers which appear to be asbestiform, there is presently no accepted method for ensuring uniformity of judgment between laboratories. It is, therefore, incumbent upon all laboratories using this method to report total fiber counts"
NIOSH Manual of Analytical Methods	"Asbestos by TEM," NIOSH Method 7402 (1 of 7) [T2-57]	"SYNONYMS [CAS#]: actinolite [77536-66-4] or ferroactinolite [15669-07-5]; amosite [12172-73-5]; anthophyllite [77536-67-5]; chrysotile [12001-29-5]; serpentine [18786-24-8]; crocidolite [12001-28-4]; tremolite [77536-68-6]; amphibole asbestos [1332-21-4]"
NIOSH Manual of Analytical Methods	"Asbestos by TEM," NIOSH Method 7402 (1 of 7) [T2-58]	"This method is used to determine asbestos fibers in the optically visible range and is intended to complement the results obtained by phase contrast microscopy (Method 7400)"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
NIOSH Manual of Analytical Methods	"Asbestos by TEM," NIOSH Method 7402 (1 of 7) T2-59	"INTERFERENCES: Other amphibole particles that have aspect ratios greater than 3:1 and elemental compositions similar to the asbestos minerals may interfere in the TEM analysis. Some non-amphibole minerals may give electron diffraction patterns similar to amphiboles. High concentrations of background dust interfere with fiber identification. Some non-asbestos amphibole minerals may give electron diffraction patterns similar to asbestos amphiboles"
US EPA/ Office of Research and Development	"Analytical Method for Determination of Asbestos Fibers in Water, Eric Chatfield and M. Jane Dillon" (1 of 3) T2-60	"Asbestos - A commercial term applied to a group of silicate minerals that readily separate into thin, strong fibers that are flexible, heat resistant and chemically inert"
U.S. EPA	"U.S. EPA Drinking Water Methods for Chemical Parameters" (1 of 1) T2-61	"Method - 100.1 Asbestos by Transmission Electron Microscopy; Title - Analytical Method for the Determination of Asbestos Fibers in Water (EPA/600/4-83-043); Method - 100.2 Asbestos by Transmission Electron Microscopy; Title - Determination of Asbestos Structures Over 10 um in Length in Drinking Water (EPA/600R-94/134)"
Code of Federal Regulations	"Subpart M - National Emission Standard for Asbestos, 40 CFR 61.141" (1 of 1) T2-62	"Asbestos means the asbestiform varieties of serpentinite (chrysotile), riebeckite (crocidolite), cummingtonite-grunerite, anthophyllite, and actinolite-tremolite"
Code of Federal Regulations	"Maximum Contaminant Levels for Inorganic Contaminants, 40 CFR 141.62" (1 of 3) T2-63	"(2) Asbestos…7 Million Fibers/liter (longer than 10 [mu]m)"
Code of Federal Regulations	"Inorganic Chemical Sampling and Analytical Requirements, 40 CFR 141.23" (2 of 5) T2-64	"Asbestos…7 MFL \1\…Transmission Electron Microscopy…Detection limit 0.01 MFL"
US Code	"15 U.S.C. 53 Sub. II Sect. 2642 Definitions" (1 of 4) T2-65	"(3) Asbestos - The term 'asbestos' means asbestiform varieties of chrysotile (serpentine); crocidolite (riebeckite); amosite (cummingtonite-grunerite); anthophyllite; tremolite or actinolite"
US EPA/ Atmospheric Research and Exposure Assessment Laboratory	"Method for the Determination of Asbestos in Bulk Building Materials, R.L. Perkins and B.W. Harvey" (pg A-1) T2-66	"Asbestiform (morphology) - Said of a mineral that is like asbestos, I.e., crystallized with the habit of asbestos. Some asbestiform minerals may lack the properties which make asbestos commercially valuable, such as long fiber length and high tensile strength. With the light microscope, the asbestiform habit is generally recognized by the following characteristics:"

Table 2. List of Citations from Relevant Regulations and Analytical Methods, continued.

TITLE	REFERENCE	CITED PASSAGE
US EPA/ Atmospheric Research and Exposure Assessment Laboratory	"Method for the Determination of Asbestos in Bulk Building Materials, R.L. Perkins and B.W. Harvey" (pg A-1)[T2-67]	* Mean aspect ratios ranging from 20:1 to 100:1 or higher for fibers longer than 5 um. Aspect ratios should be determined for fibers, not bundles"; very thin fibrils, usually less than 0.5 micrometers in width and …; two or more of the following: parallel fibers occurring in bundles, fiber bundles displaying splayed ends, matted masses of individual fibers, and/or fibers showing curvature
US EPA/ Atmospheric Research and Exposure Assessment Laboratory	"Method for the Determination of Asbestos in Bulk Building Materials, R.L. Perkins and B.W. Harvey" (pg A-1)[T2-68]	"These characteristics refer to the population of fibers as observed in a bulk sample. It is not unusual to observe occasional particles having aspect ratios of 10:1 or less, but it is unlikely that the asbestos component(s) would be dominated by particles (individual fibers) having aspect ratios <20:1 for fibers longer than 5um. If a sample contains a fibrous component of which most of the fibers have aspect ratios of <20:1 and that do not display the additional asbestiform characteristics, by definition the component should not be considered asbestos"
US EPA/ Atmospheric Research and Exposure Assessment Laboratory	"Method for the Determination of Asbestos in Bulk Building Materials, R.L. Perkins and B.W. Harvey" (pg A-1)[T2-69]	"Asbestos - A commercial term applied to the asbestiform varieties of six different minerals. The asbestos types are chrysotile (asbestiform serpentine), amosite (asbestiform grunerite), crocidolite (asbestiform riebeckite), and asbestiform anthophyllite, asbestiform tremolite, and asbestiform actinolite. The properties of asbestos that caused it to be widely used commercially are: 1) its ability to be separated into long, thin, flexible fibers; 2) high tensile strength; 3) low thermal and electrical conductivity; 4) high mechanical and chemical durability, and 5) high heat resistance"
Code of Federal Regulations	"Mandatory Health Standards, 30 CFR 71.702 Subpart H Airborne Contaminants" (pg 1 of 1)[T2-70]	"As used in this subpart, the term asbestos means chrysotile, amosite, crocidolite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos but does not include nonfibrous or nonasbestiform minerals"
Code of Federal Regulations	"Exposure Limits for Airborne Contaminants," 30 CFR 56.5001 (1 of 1)[T2-71]	"Asbestos is a generic term for a number of hydrated silicates that, when crushed or processed, separate into flexible fibers made up of fibrils…"

Table 3. Asbestos Content of the Fine Fraction of Vermiculite Attic Insulation. Asbestos content determined using scanning electron microscopy.

Building	Location	Weight % > 0.5 mm	Weight % < 0.5 mm	Wt. % Asbestos in Fines	Wt% Fine Asbestos in Sample
Marco Barbanti 418 E. Wellesley Spokane, WA	Top	98.82	1.18	0.065	0.0008
	Middle	98.10	1.90	0.314	0.0060
	Bottom	98.24	1.76	0.044	0.0008
	Combined	98.42	1.58	0.146	0.0023
	Top	98.91	1.09	0.105	0.0011
	Middle	98.66	1.34	0.182	0.0024
	Bottom	99.32	0.68	0.465	0.0032
	Combined	98.97	1.03	0.214	0.0022
	Top	98.92	1.08	1.204	0.0129
	Middle	99.49	0.51	0.108	0.0006
	Bottom	99.69	0.31	1.453	0.0045
	Combined	99.32	0.68	0.992	0.0068
	Top	99.67	0.33	0.523	0.0017
	Middle	99.78	0.22	0.781	0.0017
	Bottom	99.68	0.32	0.892	0.0029
	Combined	99.71	0.29	0.737	0.0021
Rosie Thurman 1803 W. Knox Spokane, WA	Top	98.12	1.88	0.071	0.0013
	Middle	98.49	1.51	0.051	0.0008
	Bottom	99.64	0.36	0.109	0.0004
	Combined	98.80	1.20	0.066	0.0008
	Top	95.70	4.30	0.033	0.0014
	Middle	95.49	4.51	0.006	0.0003
	Bottom	97.30	2.70	0.033	0.0009
	Combined	96.16	3.84	0.021	0.0008

Table 3. Asbestos Content of the Fine Fraction of Vermiculite Attic Insulation. Asbestos content determined using scanning electron microscopy, continued.

Building	Location	Weight % > 0.5 mm	Weight % < 0.5 mm	Wt. % Asbestos in Fines	Wt% Fine Asbestos in Sample
Marco Barbanti 1301 W. Malcon Spokane, WA	Top	97.75	2.25	0.813	0.0183
	Middle	98.78	1.22	0.088	0.0011
	Bottom	97.58	2.42	0.030	0.0007
	Combined	98.06	1.94	0.142	0.0028
	Top	98.20	1.80	0.014	0.0003
	Middle	98.46	1.54	0.008	0.0001
	Bottom	98.99	1.01	0.172	0.0017
	Combined	98.62	1.38	0.060	0.0008
Ralph Busch 1512 W 14th Ave Spokane, WA	Top	99.73	0.27	0.245	0.0007
	Middle	99.57	0.43	0.134	0.0006
	Bottom	99.64	0.36	0.553	0.0020
	Combined	99.64	0.36	0.297	0.0011
	Top	99.43	0.57	0.160	0.0009
	Middle	99.60	0.40	0.458	0.0018
	Bottom	99.27	0.73	0.661	0.0048
	Combined	99.43	0.57	0.452	0.0026
	Debris	97.47	2.53	0.331	0.0084
Benny King 9909 East Garland Spokane, WA	Top	97.36	2.64	1.300	0.0344
	Middle	92.76	7.24	0.068	0.0049
	Bottom	92.17	7.83	0.066	0.0052
	Combined	93.36	6.64	0.171	0.0113
	Top	96.87	3.13	0.122	0.0038
	Middle	95.66	4.34	0.134	0.0058
	Bottom	95.07	4.93	0.080	0.0039
	Combined	95.87	4.13	0.111	0.0046

Table 3. Asbestos Content of the Fine Fraction of Vermiculite Attic Insulation. Asbestos content determined using scanning electron microscopy, continued.

Building	Location	Weight % > 0.5 mm	Weight % < 0.5 mm	Wt. % Asbestos in Fines	Wt% Fine Asbestos in Sample
Ernest Matthews 2207 S Adams Rd Veradale, WA	Top	99.26	0.74	0.077	0.0006
	Middle	98.11	1.89	0.009	0.0002
	Bottom	99.37	0.63	0.186	0.0012
	Combined	98.94	1.06	0.061	0.0006
	Top	98.95	1.05	0.003	0.0000
	Middle	96.95	3.05	0.008	0.0002
	Bottom	99.27	0.73	0.102	0.0007
	Combined	98.31	1.69	0.020	0.0003
	Top	97.71	2.29	0.005	0.0001
	Middle	99.67	0.33	0.134	0.0004
	Bottom	99.04	0.96	0.039	0.0004
	Combined	98.85	1.15	0.028	0.0003
Paul Price 3905 Montana Hwy 40 West Columbia Falls, MT	Top	99.13	0.87	0.102	0.0009
	Middle	98.73	1.27	0.118	0.0015
	Bottom	98.70	1.30	0.016	0.0002
	Combined	98.91	1.09	0.085	0.0009
	Top	98.44	1.56	0.030	0.0005
	Middle	94.39	5.61	0.030	0.0017
	Bottom	95.97	4.03	0.049	0.0020
	Combined	96.49	3.51	0.036	0.0013
John Holbrook 328 South 5th West Missoula, MT 59801	Top	99.25	0.75	0.117	0.0009
	Middle	98.47	1.53	0.101	0.0015
	Bottom	97.90	2.10	0.033	0.0007
	Combined	98.36	1.64	0.063	0.0010

Table 3. Asbestos Content of the Fine Fraction of Vermiculite Attic Insulation. Asbestos content determined using scanning electron microscopy, continued.

Building	Location	Weight % > 0.5 mm	Weight % < 0.5 mm	Wt. % Asbestos in Fines	Wt% Fine Asbestos in Sample
	Top	98.21	1.79	0.132	0.0024
	Middle	98.05	1.95	0.104	0.0020
	Bottom	98.37	1.63	0.213	0.0035
	Combined	98.19	1.81	0.140	0.0025
John Prebil 624 South 5th West Missoula, MT 59801	Top	98.75	1.25	0.302	0.0038
	Middle	97.95	2.05	0.053	0.0011
	Bottom	98.30	1.70	0.342	0.0058
	Combined	98.29	1.71	0.199	0.0034
	Top	98.57	1.43	0.249	0.0036
	Middle	98.36	1.64	0.186	0.0030
	Bottom	97.84	2.16	0.282	0.0061
	Combined	98.16	1.84	0.251	0.0046

Table 4. Ambient Air Concentrations From Samples Collected Indoor and Outdoor At Homes Containing Alleged Zonolite Attic Insulation.

Location		Fibers 5mm				All Fiber Sizes			
		Indoor		Outdoor		Indoor		Outdoor	
Residence	Address	S/mm^2	S/cc	S/mm^2	S/cc	S/mm^2	S/cc	S/mm^2	S/cc
Barbanti	Washington State	0	0	0	0	1.8	0.0003	0	0
Barbanti	Spokane, WA	0	0	0	0	0	0	0	0
Busch	Spokane, WA	0	0	0	0	0	0	0	0
Hatch	Washington State	0	0	0	0	0	0	5.6	0.0010
Holbrook	Missoula, MT	0	0	0	0	0	0	0	0
King	Washington State	0	0	0	0	0	0	0	0
Lindholm	Andover, MA	0	0	0	0	0	0	0	0
Mathews	Washington State	0	0	0	0	0	0	0	0
Prebil	Helena, MT	1.9	0.0004	0	0	1.9	0.0004	0	0
Price	Columbia Falls, MT	0	0	0	0	0	0	0	0
Szufnarowksi	Chelmsford, MA	0	0	0	0	0	0	0	0
Thurman	Washington State	0	0	0	0	0	0	0	0

Samples analyzed using AHERA method (40 CFR 763, Appendix A to Subpart E).

Table 5. Summary of Personal Task Concentrations During the Simulations by Lees and Mlynarek, Including Comparative Reduction in Concentration from One Measurement Technique Relative to Another.

Test	Job Title	Time, min	Task Concentrations, f/cc PCM	PCME Amphibole	PCME Asbestos	Reduction in Concentration PCM / PCME Amphibole	PCM / PCME Asbestos	PCME Amphibole / PCME Asbestos
General Labor / Cleaning								
1-D	Bystander A	43	0.146	0	0			
1-K	Bystander A	26	0.082	0	0			
1-S	Bystander A	44	0.038	0	0			
1-D	Bystander B	43	0.170	0	0			
1-K	Bystander B	26	0.076	0	0			
1-S	Bystander B	44	0.040	0	0			
1-D	Helper A	42	0.134	0	0			
1-K	Helper A	25	0.123	0	0			
1-S	Helper A	45	0.078	0	0			
1-D	Helper B	42	0.116	0	0			
1-K	Helper B	25	0.136	0	0			
1-S	Helper B	45	0.053	0	0			
1-D	Worker A	42	0.623	0.010	0	62.3	NA	NA
1-K	Worker A	26	0.652	0.147	0	4.4	NA	NA
1-S	Worker A	42	0.353	0.091	0.007	3.9	50.4	13.0
1-D	Worker B	42	0.510	0.006	0	85.0	NA	NA
1-K	Worker B	26	0.522	0.010	0.010	52.2	52.2	1.0
1-S	Worker B	42	0.368	0.087	0	4.2	NA	NA
Small Scale Removal								
1-F	Bystander A	21	0.085	0	0			
1-M	Bystander A	11	0.054	0	0			
1-F	Bystander B	21	0.153	0	0			
1-M	Bystander B	11	0.114	0	0			
1-F	Helper A	21	0.105	0	0			
1-M	Helper A	12	0.098	0.586	0.174			
1-F	Helper B	21	0.125	0.010	0			
1-M	Helper B	12	0.301	0.082	0.034			

Table 5. Summary of Personal Task Concentrations During the Simulations by Lees and Mlynarek, Including Comparative Reduction in Concentration from One Measurement Technique Relative to Another, continued.

Test	Job Title	Time, min	Task Concentrations, f/cc			Reduction in Concentration		
			PCM	PCME Amphibole	PCME Asbestos	PCM / PCME Amphibole	PCM / PCME Asbestos	PCME Amphibole / PCME Asbestos
1-F	Worker A	21	1.233	0.519	0.194	2.4	6.4	2.7
1-M	Worker A	11	1.699	0.616	0	2.8	NA	NA
1-F	Worker B	21	1.044	0.571	0.116	1.8	9.0	4.9
1-M	Worker B	11	1.931	1.216	0.161	1.6	12.0	7.6
Large Scale Removal								
1-O	Bystander A	24	0.048	0	0			
1-Q	Bystander A	23	0.060	0	0			
1-O	Bystander B	24	0.037	0	0			
1-Q	Bystander B	23	0.055	0	0			
1-O	Helper A	24	0.705	0.518	0.020			
1-Q	Helper A	21	0.502	0.457	0.065			
1-O	Helper B	24	0.678	0.626	0.070			
1-Q	Helper B	21	0.414	0.595	0.066			
1-O	Worker A	24	2.996	2.077	0.389	1.4	7.7	5.3
1-Q	Worker A	22	2.254	2.006	0.033	1.1	68.3	60.8
1-O	Worker B	24	2.742	3.185	0.327	0.9	8.4	9.7
1-Q	Worker B	22	2.003	3.059	0.030	0.7	66.8	102.0
Renovations								
1-H	Bystander A	167	0.104	0	0			
1-H	Bystander B	167	0.146	0	0			
1-H	Helper A	167	0.140	0.002	0.002			
1-H	Helper B	168	0.112	0	0			
1-H	Worker A	189	0.813	0.324	0.043	2.5	18.9	7.5
1-H	Worker B	186	0.910	0.196	0.006	4.6	151.7	32.7

NA – not determined